

STUDIES IN THE GENUS *CERATIUM* SCHRANK WITH REFERENCE TO SPECIMENS COLLECTED IN THE AGULHAS CURRENT: 2. SECTION *MACROCERAS* OSTENFELD, SUBSECTIONS *ROBUSTA* KARSTEN AND *REFLEXA* (JÖRG.) REINECKE.

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ABSTRACT

The use of polar coordinates in the measurement of antapical horn curvature in Section *Macroceras* Ostf.* is discussed, followed by a taxonomic account of Subsections *Robusta* Karsten and *Reflexa* (Jörg.) Rein. with reference to specimens collected in the Agulhas current during I.G.Y. 1958.

UITTREKSEL

STUDIES IN DIE GENUS *CERATIUM* SCHRANK MET VERWYSING NA MONSTERS IN DIE AGULHASSTROOM VERSAMEL: 2: SEKSIE *MACROCERAS* OSTENFELD, SUBSEKSIES *ROBUSTA* KARSTEN EN *REFLEXA* (JÖRG.) REINECKE.

Die gebruik van polêre koördinate vir die meet van antapikale horing geboëheid in die Seksie *Macroceras* Ostf. word bespreek, gevolg deur 'n taksonomiese behandeling van die Subseksies *Robusta* Karsten en *Reflexa* (Jörg.) Rein. met verwysing na monsters wat gedurende die Internasionale Geofisiese Jaar, 1958, in die Agulhasstroom geneem is.

THE USE OF POLAR COORDINATES IN MEASURING ANTAPICAL HORN CURVATURE IN SECTION *MACROCERAS* OSTF.

INTRODUCTION: Species in the Subgenus *Orthoceratium* Sournia, in particular those belonging to Section *Macroceras*, are classified largely on the curvature of the antapical horns. Features of antapical horn curvature which vary in this Section are: the degree to which the horns are curved posteriorly, the nature of the recurvature forwards, which varies from gradual to abrupt, and the disposition of the anteriorly directed parts, ranging from spreading to almost parallel to one another and the apical horn. The antapical horns may lie in the same plane as the dorsiventrally flattened body, to almost at right angles ventral to the body plane.

The curvature of the antapical horns is a character difficult to express numerically. The only way to determine the curvature of the antapicals away

* The epithet of a subdivision of a genus must take the same form as the generic name, or that of a plural adjective agreeing in gender with the generic name. The section name *Macroceras* as originally given by Ostensfeld (1903) is thus correct, and is incorrectly spelled by Reinecke (1971). The specific epithet in *Ceratium macroceras* (Ehb.) Vanhoeffen is treated as a substantive, and the original spelling of Ehrenberg (1840) retained.

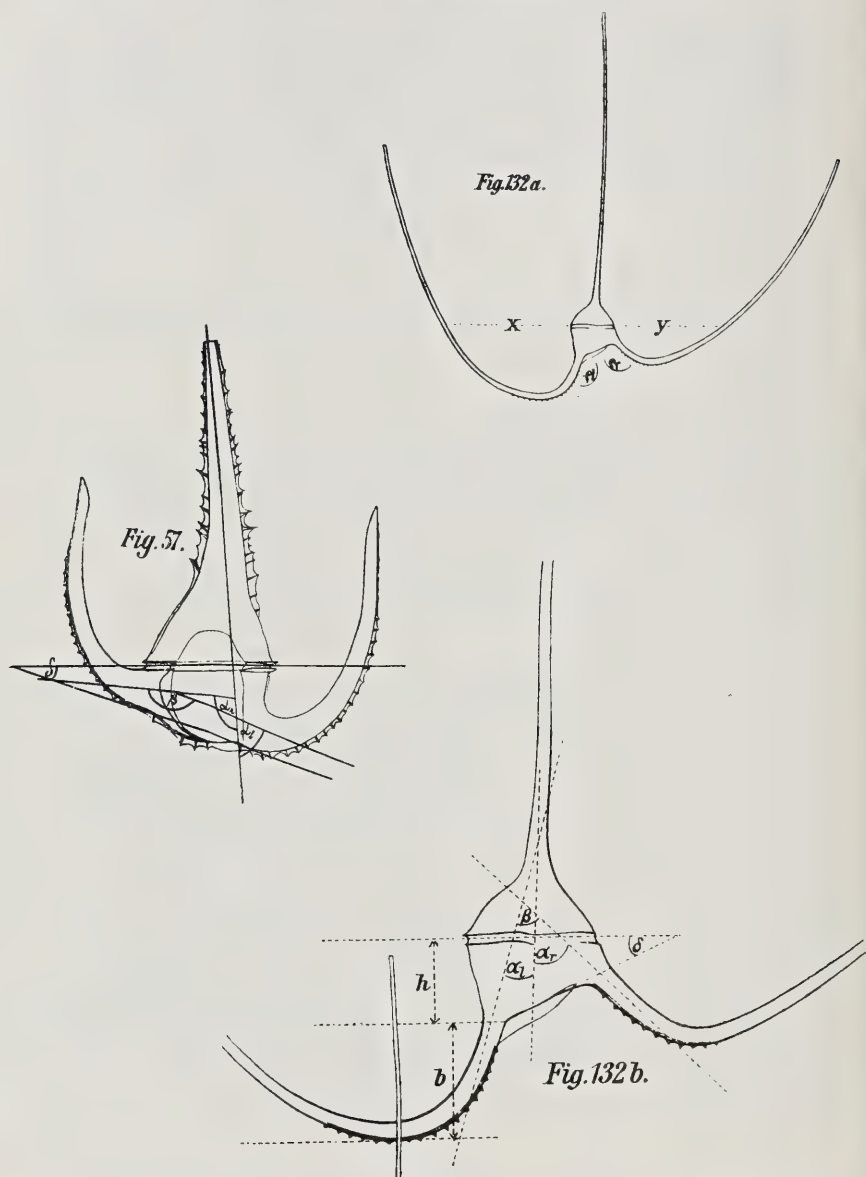


FIG. 1.
Showing the system of lines and angles used by Jörgensen to measure the various features in *Ceratium*. (Jörgensen (1911) Pl. 3, fig. 57, Pl. 8, fig. 132 a, b.)

from the body plane is by means of a graduated fine adjustment focussing screw, and this method is not satisfactory. Jørgensen (1911) used a system of lengths and angles taken from camera lucida drawings to measure the two-dimensional curvature of the horns, but this was unsatisfactory because the points where some of the measurements were taken could not be well defined. (See Fig. 1.)

Yarranton (1967) devised a better method of measuring horn curvature by using polar coordinates. Placing camera lucida drawings of full dorsal or ventral aspects on polar coordinate graph paper, and taking as a base line, a line passing through the base of each horn, oriented parallel to a line joining the midpoints of the girdle at the edges of the cell, in the case of the apical horn, and perpendicular to the girdle line for the antapical horns, he measured the degree and radius coordinates along the middle of each horn. From these readings which gave second order curves in the taxa he studied, he calculated the parameters of the curves by the method of averages.

Yarranton examined four taxa, which he considered to be all members of "Section *Euceratium*": "*C. tripos*, *C. horridum*, *C. longipes* and *C. arcticum*". His results showed little variation within each taxon and sufficient discontinuity between the taxa to provide a satisfactory measure of the difference between the four.

METHOD: An attempt was made to classify specimens of Section *Macrocercas* from the Agulhas current NGY samples using Yarranton's method. The girdle was not used as a means of orientation, as in some specimens it is incompletely formed. On the camera lucida drawings, a line referred to as the posterior line, was drawn to pass through the antapical horns at their inception, immediately adjacent to the posterior margin of the hypotheca. Perpendiculars to this posterior line were drawn through these points of inception, and taken as base lines. Using polar coordinate graph paper, in this case marked in radius intervals approximately equivalent to $3\ \mu$ on the scale of the camera lucida drawings, the curvature of the antapical horns was measured in degrees at 5 radius unit intervals, (approximately $15\ \mu$), along the outer side of the horn, excluding lists if present. (See Fig. 2.)

For each taxon, the mean and standard deviation for the set of readings at successive $15\ \mu$ intervals were calculated, and graphs plotted to show the mean curvature of the antapical horns. The mean rate of change of direction of antapical horn curvature, measured in degrees over $15\ \mu$ intervals was also plotted. (See Fig. 4A-D.)

USE OF A POLYNOMIAL REGRESSION CALCULATION: Using the first ten pairs of polar coordinates from the $15\ \mu$ to the $150\ \mu$ radius, in a computerised polynomial regression calculation, the intercepts and regression coefficients for this part of the curve of the left antapical horn were determined for a selection of

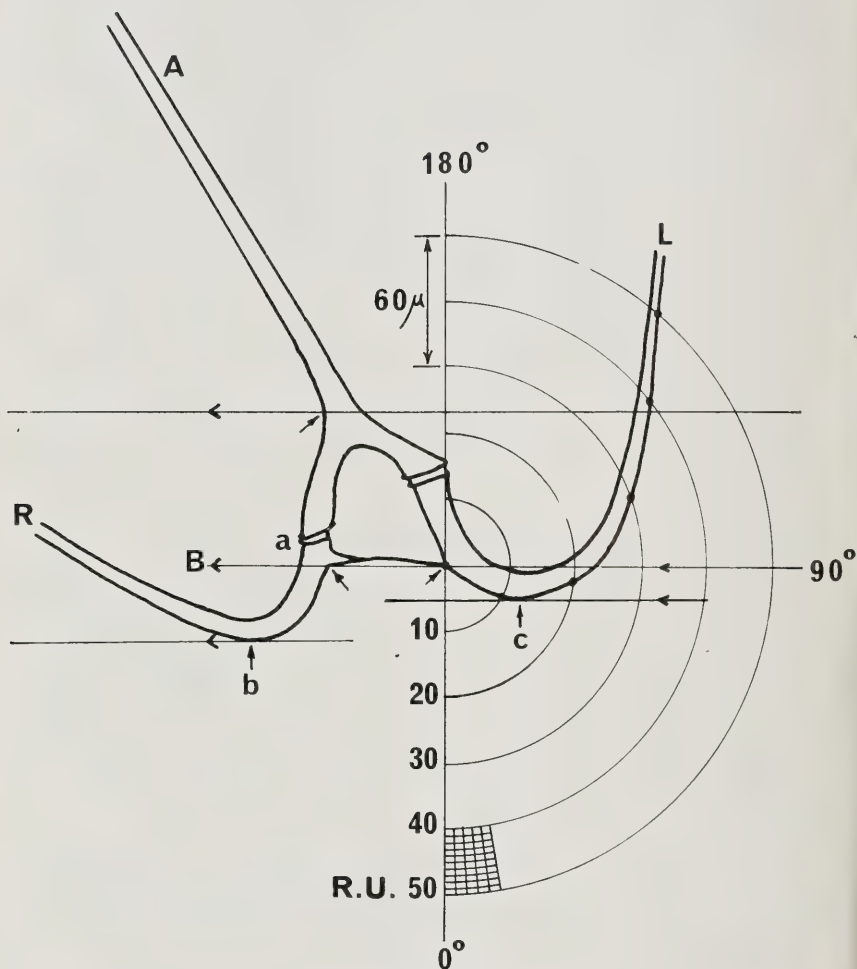


FIG. 2.

Showing how curvature of the left antapical horn is measured using polar coordinate graph paper. The arrows indicate the zero points for all three horns and the points of maximum backward curvature, (MBC), of the antapical horns. *A*, apical horn; *L* and *R*, left and right antapical horns; *B* posterior line; *a*, girdle; *b* and *c*, points of maximum backward curvature of antapical horns; *R.U.*, radius unit, one radius unit is approximately equal to 3μ .

specimens. Regressions were generally to the third degree, with about a third of the specimens showing a regression to the fourth degree. (See Appendix Table 1.)

These results are of no practical taxonomic use, chiefly because of the great variability in the curvature of the horns not encountered by Yarranton. The polar coordinates themselves, however, provide a satisfactory means of expressing horn curvature numerically.

TERMINOLOGY: The use of polar coordinates facilitates the construction of keys to, and taxonomic descriptions of, species of Section *Macroceras*, and the resultant terminology is given below:

Polar coordinates—degree and radius coordinates used here as a means of measuring the curvature of the antapical horns, plotted on camera lucida drawings of full ventral or dorsal aspect, at intervals of 15 μ , along the edges of the horns initially adjacent to the base of the hypotheca.

Radius unit—on the scale of the camera lucida drawings and the polar coordinate graph paper used, one radius unit is approximately equal to 3 μ . As this is only approximate, the radius coordinates are sometimes given in radius units or R.U.

Zero point for radius coordinates—the point of inception of the antapical horn immediately adjacent to the base of the hypotheca.

Posterior line—a line drawn to pass through the bases of the antapical horns at their inception immediately adjacent to the posterior margin of the hypotheca.

Zero line for degree coordinates—determined by drawing lines through the zero points of the right and left horns perpendicular to the posterior line.

MRC—the maximum rate of change of direction of curvature of a horn, measured in degrees over 15 μ after the initial curvature from 0–15 μ . (Very rarely, the MRC occurs over two, in exceptional cases three, successive 15 μ intervals.)

MBC—the point of maximum backward curvature of the horns determined by the construction of a tangent to the posterior or lower edge of the antapical horn parallel to the posterior line.

In addition, the ratios $\frac{B}{H}$ and $\frac{L90}{D}$ and $\frac{R90}{D}$, first defined by Jørgensen (1911),

are of use in delimiting some of the taxa:

H is the perpendicular distance between a line joining the profile edges of the lower rim of the girdle and a line parallel to it through the left horn zero point for the radius coordinates.

B is the perpendicular distance between this latter line and a line parallel to it drawn as a tangent to the lower edge of the left antapical horn.

L90 and *R90* are the left and right horn radius coordinates with the 90° coordinate.

D is the diameter of the body measured in radius units.

The apical horn lies roughly perpendicular to the girdle in the specimens examined. Polar coordinates of this horn were measured along the left edge, with the base line a line drawn through the base of the horn parallel to the posterior line. The polar coordinates may indicate a very slight curvature of the apical horn, of insignificant use as a taxonomic character.

Subgenus *ORTHOCERATIUM* Sournia (1967): 376.

Gen. *Ceratium* Vanhöffen (1896): 133.

Sect. *Euceratium* Gran (1902): 192.

Subgen. *Euceratium* (Gran) Ostensfeld (1903): 583.

Diagnosis: Differs from the other Subgenera in that, in normal vegetative cells, both antapical horns, very rarely only one, are either anteriorly directed from their inception, or at first posteriorly directed and then recurved forwards.

A key to the Sections will be given in a later paper.

Section *MACROCERAS* Ostensfeld (1903): 584.

Sect. *Protuberantia* Karsten (1907): 404.

Subgen. *Macroceratium* Kofoid (1909): 218.

Böhm (1931b): 35.

Diagnosis: Distinguished by the curvature of the antapical horns, one or both of which are initially backwardly directed, usually markedly so; both antapical horns more or less similar in length.

KEY TO SUBSECTIONS

I Left antapical horn abruptly recurved before the 90° coordinate, so that it is posteriorly directed and lies roughly in line with the apical horn (See Fig. 7 H.)

Subsection *Reflexa*

II Left antapical horn never thus recurved.

(i) Chain formation rare, length of apical horn of posterior members of complete chain > 0,4 length of apical horn of front cell of chain.

Subsection *Macroceras*

(ii) Chain formation common, length of apical horn of posterior members of complete chain < 0,4 that of front cell of chain.

Subsection *Robusta*

HISTORY: Ostensfeld (1903) distinguished between Section *Tripus* Ostf. and Section *Macroceras* on the grounds of closed distal ends to the antapical horns and spineless lists in the former, and antapicals with open distal ends and spiny lists in the latter. Karsten (1907) characterised Section *Protuberantia* as having the antapicals initially backwardly directed and then recurved anteriorly. He

divided this Section into Subsections: "*Ceratium tripos volans*, *C. tripos flagelliferum*, *macroceras*, *tergestina* and *robusta*", each of which corresponded to a single species, part of a species complex, or incorporated several species. Kofoid (1909) defined Subgenus *Macroceratium* as having antapical horns as in *Protuberantia* Karst., with the tips "truncate, open or contracted or rounded, but usually with a terminal pore". Jørgensen (1911) described Section *Macroceras* as having "both antapicals curved forward, open at the tip or rarely with closed ends, at least one antapical initially projecting more or less distinctly backwards . . . antapicals usually approximately the same length; this is however very variable within a single species; usually one to three more or less large wings at the base of the cell, which in Section *Tripos* are usually missing or very indistinct, with the exception of *C. compressum*, where they are similarly constructed." Jørgensen divided Section *Macroceras* into seven Subsections: "*Deflexa*, *Volantia*, *Vultur*, *Flagellifera*, *Tenuia*, *Intermedia* and *Reticulata*". This subdivision has not been followed by later authors, apart from Böhm (1931b), who divided "Subgenus *Macroceratium*" into Sections *Macroceras*, *Vultur*, *Trichoceros* and *Reticulata*. Section *Reticulata* (Jörg.) Böhm should be retained, in view of the peculiar hexagonal patterning of the thecal plates and the unusual alignment of the antapical horns.

Horn length and nature of ends of horns: Ostenfeld (1903) appears to have been the first author to comment on the nature of the ends of the antapical horns in this Section. Karsten (1905) in his description of "*C. tripos macroceras*" wrote: "sometimes the tips of the antapical horns are distinctly transversely truncate and open, without a piece appearing to be missing, in other cases they are certainly closed, which can be established especially when the ends are inflated . . . it is not unlikely that different stages of development are represented". In an illustration of a specimen of the *C. vultur* complex, "*C. tripos robustum*", Karsten (1907) shows the distal ends of the antapical horns fairly abruptly constricted and tapering to a tip terminating in a pore, (See Fig. 6T.) He also depicts antapical horn tips of specimens of Subsection *Macroceras* with rounded closed apices and slightly tapered open apices, (1907, Pl. 49). Pavillard (1907) wrote: "it is possible that the open ends, if constant in Section *Macroceras*, are the result of an early amputation, the mechanism of which is unknown." Kofoid (1908) came to the conclusion that the distal parts of the horns, in particular of the long-horned species, could be shed actively, a process he termed autotomy, and regenerate. He suggested that this was a flotation mechanism.

The nature of the ends of the antapical horns in Section *Macroceras* does not appear to have been discussed by later authors. The apical horn terminating in the apical pore, always has a truncate end, and usually it is not possible to determine whether or not the horn has been broken. In NGY specimens

belonging to this Section, the antapical horns were most frequently truncate, while in most specimens belonging to other Sections of the Subgenus *Orthoceratium*, the distal ends of the antapical horns tapered, with a decrease in wall thickness, to a closed point. Where the antapical horns were truncate, the wall of the horn was either of a uniform thickness, with an apparently open end, or the wall became gradually thinner distally, the horn tapering and ending in a rounded, rather than an abruptly truncate tip, which was occasionally slightly inflated. In the latter case, it was impossible to determine whether or not the end terminated in a pore. Cases of regeneration were observed, indicated by an abrupt transition between the thin-walled regenerated distal part and the thick-walled proximal part.

The foregoing indicates the difficulty in determining true horn length in specimens belong to this Section. Apical horn length along chains is, however, of importance in distinguishing between Subsections *Macroceras* and *Robusta*. (See Fig. 3.)

Subsection ROBUSTA Karsten (1907): 413.

Subsect. *Vultur* Jörgensen (1911): 71.

DIAGNOSIS: Differs from the other Subsections in that chain formation is common and the length of the apical horn in posterior members of the chain is less than 0,4 that of the anterior cell in a complete chain.

KEY TO SPECIES AND FORMS (Based upon polar coordinate measurements of antapical horn curvature. See Appendix Tables 2 and 3, and Fig. 4A-D.)

I Distal part of left antapical horn markedly recurved.

- (i) Zone of recurvature markedly angled and occurring between the 45 and 75 μ radius coordinates. *C. recurvum*

- (ii) Zone of recurvature gradual and occurring beyond the 120 μ radius coordinate. *C. vultur f. valdiviae*

II Distal part of left antapical horn not, or only very slightly recurved.

- (i) Left horn MBC radius coordinate $> 30 \mu$.

- (1) Left horn MRC $\geq 45^\circ$.

C. vultur f. japonicum

- (2) Left horn MRC $< 40^\circ$.

C. vultur f. vultur

- (ii) Left horn MBC radius coordinate $= 30 \mu$.

- (1) Left horn degree coordinate with 150 μ radius coordinate $> 150^\circ$.

C. vultur f. vultur

- (2) Left horn degree coordinate with 150 μ radius coordinate $< 150^\circ$.

C. vultur f. valdiviae

- (iii) Left horn MBC radius coordinate $< 30 \mu$.

- (1) Left horn MRC occurs between 60 and 90 μ radius coordinates.

C. vultur f. neglectum

- (2) Left horn MRC occurs before 45 μ radius coordinate.

- (a) Left horn degree coordinate with 30 μ radius coordinate $\geq 100^\circ$.

- (b) Specimen from the Mediterranean.

C. vultur var. pavillardii

- (bb) Specimen from other waters.

C. vultur f. sumatranum

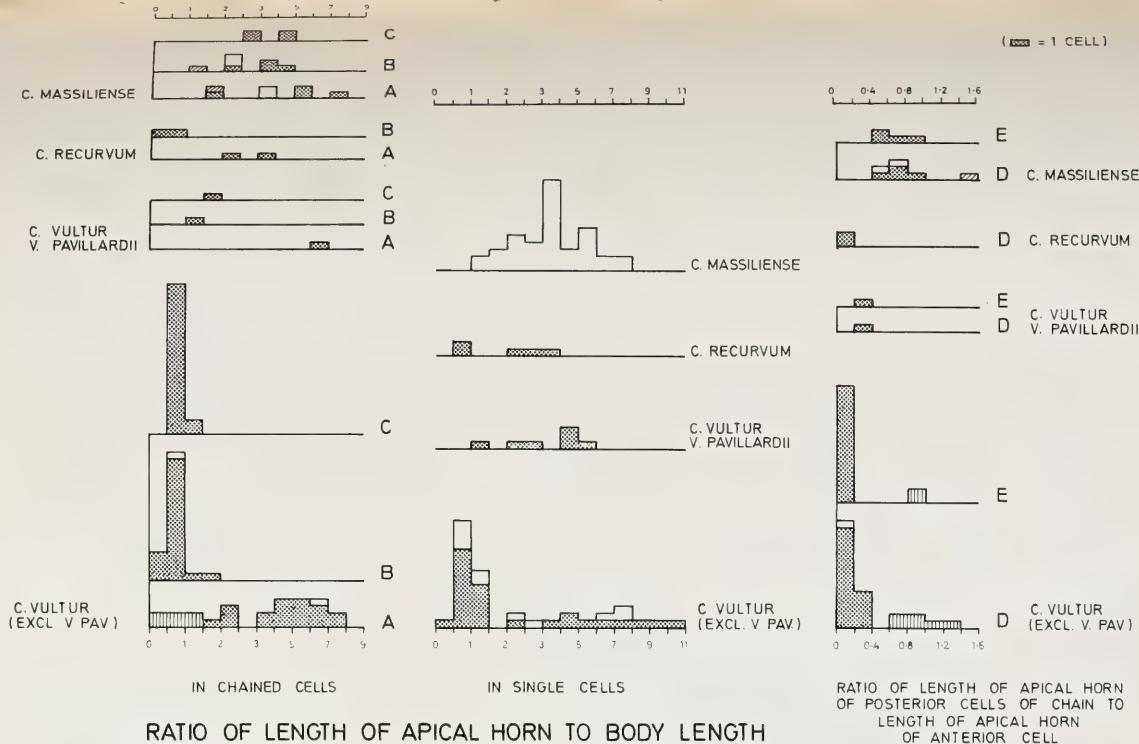


FIG. 3.

Histograms showing variation in length of apical horn in Subsection *Robusta* Karst. compared with *C. massiliense* (Gourret) Karsten and a heteromorphic chain of *C. macroceros* (Ehb.) Vanhoeffen, (in which the antapical horns of the anterior cell are short and straight). The white shading refers to specimens from Agulhas current NGY samples; the dotted to specimens from the literature; the vertical hatching to chains of *C. vultur* Cl. figured in the literature, in which the fragment of chain depicted lacked the long-apical-horned anterior cell; the diagonal hatching to the chain of *C. macroceros*. The only chains of Subsection *Macroceras* Jörg. depicted in the literature examined, (Kofoid (1908) fig. 10; Jörgensen (1911) Pl. 1, fig. 6; Graham & Bronikowsky (1944) figs. 22 E, F; Wood (1954) fig. 235a), and all the figures of *C. vultur* cited in the text, are referred to. *A* refers to first cell of chain, *B* to second cell of chain, *C* to rest of cells of chain; *D* refers to ratio of length of apical horn of second cell of chain to that of first cell, *E* to ratio of length of apical horns of rest of cells of chain to that of first cell. (It is possible that the apical horn was broken in NGY specimens of *C. massiliense* with a low value for the ratio apical horn length: body length.)

- (aa) Left horn degree coordinate with $30\ \mu$ radius coordinate $< 100^\circ$.
- (c) Right horn MBC radius coordinate $> 22\ \mu$, left horn degree coordinate with $90\ \mu$ radius coordinate $< 145^\circ$.
- (cc) Right horn MBC radius coordinate $< 22\ \mu$, left horn degree coordinate with $90\ \mu$ radius coordinate $> 145^\circ$.

C. vultur f. valdiviae

C. vultur f. sumatranum

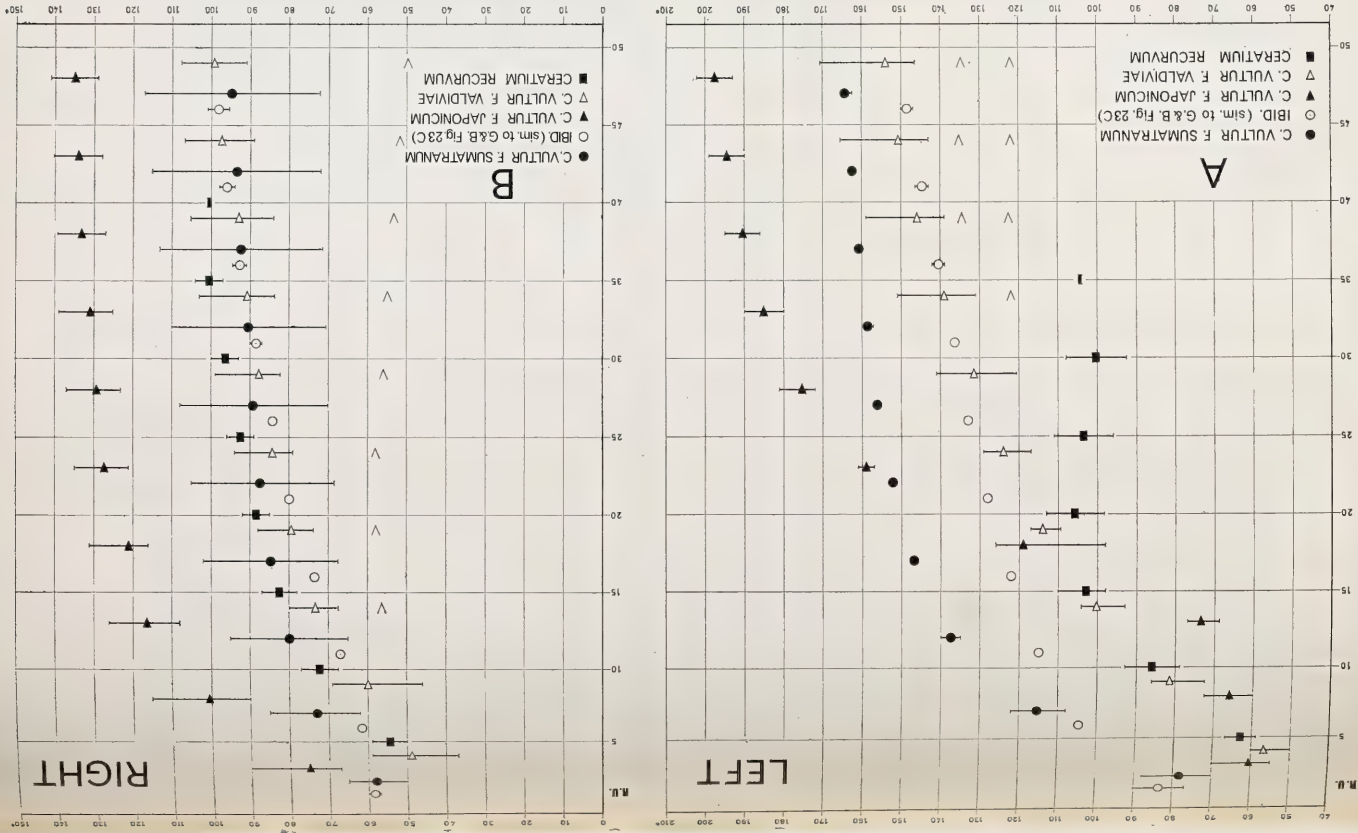
Members of Subsection *Robusta* are not common in phytoplankton samples, and extensive use had to be made of figures from the literature to obtain a good picture of taxonomic variation. Unfortunately these figures are not always accurate (such as Schröder's (1900) illustration of a chain of "*C. tripos* var. *macroceras f. undulata*", see Fig. 5A).

The retention of this Subsection is justified by the difference between the apical horn length of the front cell of a complete chain and that of the rest of the cells. In 63% of the cells belonging to this Subsection figured in the literature and found in the Agulhas current NGY samples, the apical horn was < 1.5 the body length, while this was the case in only 4.5% of the NGY cells of *C. massiliense* (Gourret) Karst., where it is possible that the apical horn was broken. (See Fig. 3.)

Culture experiments on members of this Subsection are needed to determine whether or not the daughter cells always adhere together forming chains for at least some time after schizogony; whether the posterior daughter cell of a division always has a short apical horn; whether a short-apical-horned cell could, on division produce a long-apical-horned cell; and whether a short apical horn could later increase in length.

Ceratium vultur Cleve (1900): 15, Pl. 7, fig. 5. (See Figs. 4-9.)

Description: An extremely variable species, forming chains, in which the length of the apical horn of the posterior cells is < 1.5 the body length and < 0.4 the length of the apical horn of the front cell. The posterior cells of a chain may also differ from the anterior cell, and sometimes from one another in the curvature of the antapical horns, the MBC degree and radius coordinates, the ornamentation of the theca, body shape and girdle diameter. *Antapical horn curvature:* The antapical horns may lie parallel to one another and the apical horn, or diverge; sometimes, usually in posterior chain cells, the distal parts are smoothly recurved. Measured values of the left horn degree coordinate with the $15\ \mu$ radius coordinate vary from $28-105^\circ$, usually $50-85^\circ$, while the equivalent right horn degree coordinate is less or greater than its left counterpart by up to 38° . The left horn MBC degree coordinate varies from $40-90^\circ$, mostly $60-80^\circ$, and the MBC radius coordinate from $6-72\ \mu$; the right horn MBC degree coordinate is from 33° less to 24° greater than that of the left horn, and the right horn MBC radius coordinate varies from $6-45\ \mu$, very rarely $60\ \mu$.



Antlaph horn curvature in NGY specimens of *C. vultur* and *C. recurvum* (Jörg.) Reinecke:
 A, curvature of the left horn expressed in polar coordinates, that is in degrees at intervals of 5 R.U., from 5 to 50 R.U., (R.U. = radius unit, one radius unit is approximately equal to 3μ); the symbols represent the mean degree coordinate values at successive 5 R.U. intervals for all specimens examined, the lines indicate the range of degree values recorded; B, the same for the right horn; half symbols represent single specimens.

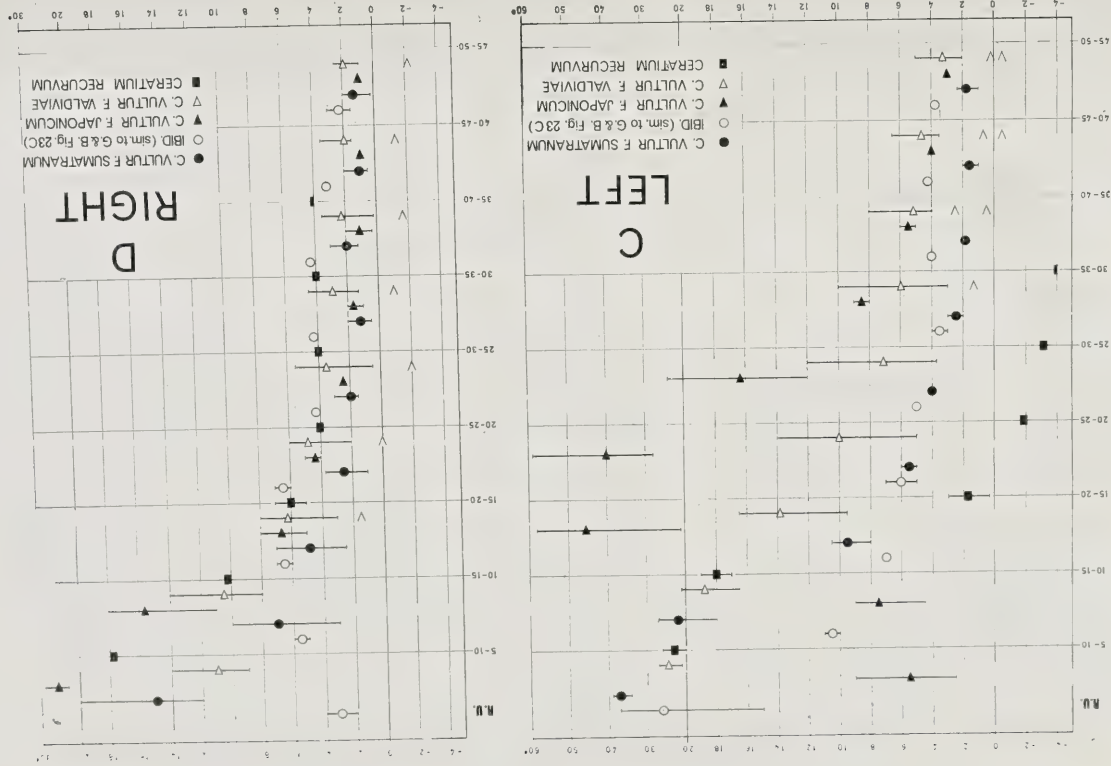


Fig. 4. (c & d) C, rate of change of direction of curvature of left horn, expressed in degrees over 5 R.U., from 5-10 to 45-50 R.U.; D, the same for the right horn, expressed in degrees over 5 R.U., from 5-10 to 45-50 R.U.; half symbols represent single specimens.

In forms with a large left horn MBC radius coordinate, the equivalent right horn coordinate is considerably smaller. *Body shape*: This varies with regard to the length-breadth ratio, the relative length of the epi- and hypo- thecae and the angle made by a projection of the girdle and the base of the hypotheca. (See Fig. 9.) *Thecal ornamentation*: Seen in full ventral aspect, lists, other than the usual sulcal list, may occur along the proximal part or almost the entire length, of the right and left sides of the apical horn, extending on to the epitheca; along the base of the hypotheca, extending onto the proximal parts, sometimes continuing for almost the entire length, of the antapical horns, and along the proximal parts or almost the entire length of their upper sutures. The margins of the lists may be smooth, serrate or denticulate; sometimes spines or denticles occur along the base of the list, not extending across it; sometimes along the apical horn and in the region of recurvature on the lower side of the left horn, (very rarely the right), one to a number of spines traverse the list as supporting spines. The degree of listing varies from the above-mentioned to complete absence. Spines and/or denticles may occur along the horns in the absence of lists, when the spines may be slightly longer along the apical horn and region of recurvature of the lower suture of the left horn, or there may be combinations such as: lists along the apical horn and spines along the lower margins of the antapicals, etc. The thecal wall varies from being thin to heavily thickened and ridged.

Distribution: *C. vultur* is a fairly rare warm water species. Graham & Bronikowsky (1944) classify it as an intolerant shade species, that is, closely restricted to waters with surface temperatures of 19°C or higher, and increasing in frequency from 0–100 m. *C. vultur* var. *pavillardii* is the only infraspecific category to be recorded from the Mediterranean. The other forms are recorded from all oceans, but only *f. japonicum*, *f. valdiviae* and *f. sumatranum* were found in the NGY samples. (See Table 1.)

This is the most variable species in the genus, and the treatment of the many infraspecific categories is a difficult problem. The various taxa recorded have been described from single cells, or short chains of similar individuals, and some of these taxa have later been found in chains with other taxa, or chains with intermediate characters have been discovered. Culture experiments, difficult to carry out because of the paucity of *C. vultur* in plankton samples, are very necessary to determine the nature of variation in this species.

Peters (1932) was the first author to consider the components of *C. vultur*, excluding var. *pavillardii*, as belonging to a single species, in which infraspecific categories were not justified. Steemann Nielsen (1934) treated these, excluding var. *pavillardii*, as varieties, but later (1939), he noted: "Beim Indischen Material war es immer möglich, *C. vultur* und *C. sumatranum* auseinanderzuhalten."

	MARCH							MAY						
NGY Stations	11*	12	13	14	15	16		41*	42	43	44	45	46	
Surface temperature	20,66	24,28	25,49	23,78	22,19	21,62		17,49	23,27	24,15	23,50	21,25	20,90	
Temperature at 100 m	13,26 (at 50 m)	17,53	19,65	19,52	18,73	18,61		16,66 (at 50 m)	12,21	19,99	20,54	20,50	20,37	
No. slides examined	4	4	4	4	4	8		4	5	7	4	4	5	
Total number ceratia	601	191	233	267	270	241	1 803	318	92	197	184	241	365	1 397
C. VULTUR F. SUMATRANUM	—	0,52%	0,42%	—	0,37%	—	0,16%	—	4,34%	1,01%	—	0,41%	—	0,50%
C. VULTUR F. VALDIVIAE	—	2,09%	1,28%	—	—	—	0,38%	—	—	—	—	—	—	0,00%
C. VULTUR F. JAPONICUM	—	—	0,42%	0,37%	—	—	0,11%	—	1,08%	—	—	—	—	0,07%
CERATIUM RECURVUM	—	—	0,85%	—	—	—	0,11%	—	—	—	—	—	—	0,00%
CERATIUM REFLEXUM	—	—	—	—	—	—	0,00%	—	—	—	—	0,41%	—	0,07%

TABLE 1.

Showing distribution and relative frequency, expressed as a percentage, of species of Subsections *Robusta* and *Reflexa* in samples from the line of NGY stations off Port Elizabeth. Apart from the * stations, net hauls examined from 100–0 m. (Temperatures in °C.)

He found their distribution and ecology identical. Graham and Bronikowsky (1944) concluded that seven varieties of *C. vultur*, including *var. pavillardii*, could be distinguished, but gave no measurements and no figures of chains.

An examination of specimens illustrated in the literature indicates no sharp visual discontinuities between the various taxa described. (See Figs. 5 and 6.) Polar coordinates of some of these were measured on enlargements similar in scale to the camera lucida drawings of the NGY specimens. While no absolute discontinuities are apparent, it is possible to construct a key using polar coordinates to all the variations depicted, bearing in mind the inaccuracies of some of the figures (see Appendix Table 2). The NGY specimens alone are easily classified into disjunct groups (see Appendix Table 3).

It is felt that a retention of infraspecific categories in this species is necessary, as the typical representatives are easily recognisable in the absence of intermediates. The use of infraspecific epithets in describing specimens of *C. vultur* in lists of phytoplankton flora serves as a brief indication of the variation of the species in the particular area under study.

The lowest botanical taxonomic ranks are those of *forma* and the rarely used *subforma*, and the concept of these varies from species to species, depending upon the nature of infraspecific variation. Here, with one exception, the rank of *forma* is applied to all reasonably disjunct taxa of *C. vultur*, bearing in mind that two forms may occur in the same chain.

Ceratium vultur f. vultur

"*C. (tripos var. ?) vultur* N.Sp." Cleve (1900): 15, Pl. 7^c fig. 5.

Okamura & Nishikawa (1904): 123, Pl. 6, Fig. 8.

C. vultur: Jörgensen (1911): 71, Pl. 8, Fig. 151a*, p.p. (posterior cell), 151b; Dangeard (1927): 378, Fig. 42b*, p.p. (posterior cell); Pavillard (1931): 93, Pl. 3, Fig. 8*; Peters (1932): 54, Pl. 1, Fig. 7b; Steemann Nielsen (1934): 27, Fig. 65; Schiller (1937): 418, Fig. 459a* (from Jörgensen (1911) Fig. 151a).

C. japonicum: Pavillard (1931): 93, Pl. 3, Fig. 9*, p.p. (posterior cell); Balech (1962): 182, Pl. 25, Fig. 393*, p.p. (posterior cell).

C. vultur f. japonicum: Wood (1954): 304, Fig. 233c*, p.p. (posterior cell).

C. pavillardii: Wood (1954): 304, Fig. 232a; *non C. pavillardii* Jörgensen.

C. tripos robustum: Karsten (1907): 413, Pl. 48, Fig. 13a*, p.p. (posterior cell), 13b.

(Intermediate between *f. vultur* and *f. valdiviae*: Jörgensen (1911) Fig. 151a, anterior cell.)

Diagnosis: Differs from *f. japonicum* with which it is sometimes associated in the same chain as the posterior member(s), in that, in the left horn the MRC is

*Chain depicted.

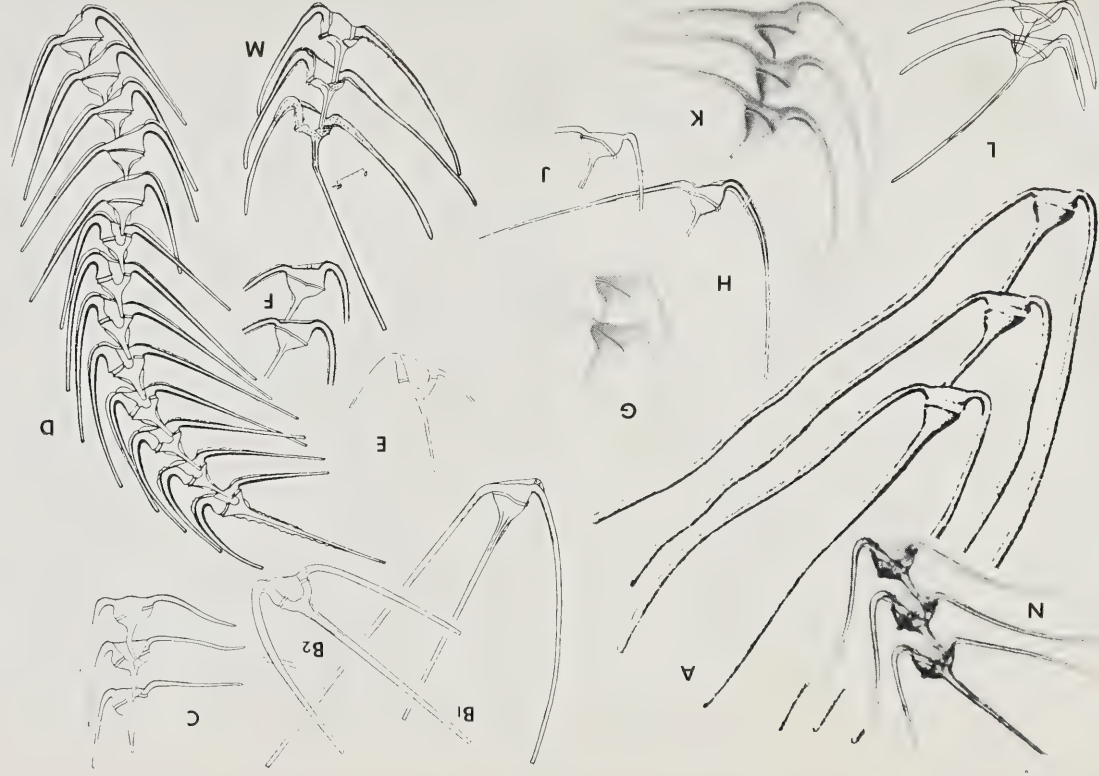


Fig. 5.

A selection of specimens of *C. vulturnus* depicted in the literature: A, Schröder (1900) Pl. 1, fig. 17m, "*C. tripos* var. *macroceras* f. *undulata*" = var. *pavillardii*; B1 Pavillard (1905) Pl. 1, fig. 2, "*C. vulturnus*" = var. *pavillardii*; B2 Rampi (1939) fig. 41, "*C. pavillardii*" = var. *pavillardii*; D Kofoid (1909) Pl. 4, fig. 7, "*C. vulturnus*" = var. *pavillardii*; E Böhm (1931a) fig. 55, "*C. vulturnus* var. *sumatranum*" = var. *pavillardii*; F Kofoid (1908) fig. 9, "*C. vulturnus*" = var. *pavillardii*; G Karsten (1907) Pl. 51, fig. 14, "*C. tripos* var. *sumatranum*" = var. *pavillardii*; H Jörgenson (1911) Pl. 8, fig. 154, "*C. sumatranum*" = var. *pavillardii*; I Ibid. fig. 155, "*C. sumatranum* f. *angulatum*" = var. *pavillardii*; J Ibid. fig. 155, "*C. sumatranum* f. *angulatum*" = var. *pavillardii*; K Karsten (1905) Pl. 19, fig. 12a, "*C. tripos* f. *neglecta*" = var. *pavillardii*; L Ostenfeld & Schmidt (1901) fig. 20, "*C. vulturnus*" = var. *pavillardii*; M Nie (1936) fig. 32, "*C. sumatranum*" = var. *pavillardii*; N Klement (1964) "*C. vulturnus*" = var. *pavillardii*.



FIG. 6.

A selection of specimens of Subsections *Robusta* and *Reflexa* depicted in the literature: **A** Karsten (1905) Pl. 19, fig. 12, "*C. tripos f. neglecta*" = *C. vultur f. neglectum* (iconotype); **B** Pavillard (1931) Pl. 3, fig. 8, "*C. vultur*" = *C. vultur f. vultur*; **C** Cleve (1900) Pl. 7, fig. 5, "*C. vultur*" = *C. vultur f. vultur* (iconotype); **D** Jörgensen (1911) Pl. 8, fig. 151a, "*C. vultur*", post. cell = *C. vultur f. vultur*, ant. cell = intermediate between *f. vultur* and *f. valdiviae*; **E** Graham & Bronikowsky (1944) fig. 23G, "*C. vultur var. regulare*" = *C. massiliense*; **F** Ibid. fig. 23B, "*C. vultur var. reversum*" = *C. vultur f. sumatranum*; **G** Jörgensen (1911) Pl. 8, fig. 153, "*C. sumatranum*" = *C. vultur f. valdiviae*; **H** Okamura (1907) Pl. 3, fig. 1a, "*C. vultur*" = *C. vultur f. valdiviae*; **J** Steemann Nielsen (1934) fig. 66, "*C. vultur var. sumatranum*" = *C. recurvum*; **K** Karsten (1907) Pl. 52, fig. 8, "*C. tripos buceros*" = *C. recurvum*; **L, M** Karsten (1907) Pl. 48, figs. 14a, b, "*C. tripos vultur*" = *C. vultur f. valdiviae*; **N** Ostenfeld & Schmidt (1901) fig. 17, "*C. robustum*" = *C. vultur f. japonicum*; **O** Böhm (1931b) fig. 35b, "*C. vultur*", ant. cell = *C. vultur f. neglectum*, post. cell = *f. japonicum*; **P** Schröder (1906) fig. 31, "*C. robustum forma*" = *C. vultur f. japonicum*; **Q** Schröder (1906) fig. 33c, "*C. japonicum*" = *C. vultur f. japonicum* (iconotype); **R** Karsten (1907) Pl. 48, fig. 13a, "*C. tripos robustum*", ant. cell = *C. vultur f. japonicum*, post. cell = *C. vultur f. vultur*; **S** Wood (1963b) fig. 53, "*C. vultur var. productum*" = *C. reflexum*; **T** Karsten (1907) Pl. 48, fig. 13c, "*C. tripos robustum*" ends of antapical horns.

$< 40^\circ$ and the degree coordinate with the $150\ \mu$ radius coordinate is $< 170^\circ$; differs from *f. neglectum* in that in the left horn the MBC radius coordinate is $\geq 30\ \mu$ and the coordinate with the $150\ \mu$ radius coordinate is $< 170^\circ$; differs from *f. valdiviae* in that in the left horn the MBC radius coordinate is generally $> 30\ \mu$ and the coordinate with the $150\ \mu$ radius coordinate is $> 150^\circ$; differs from *f. sumatranum* in that the left horn MBC radius coordinate is $\geq 30\ \mu$. (See Fig. 6B–D, R.)

Dimensions: From literature: Jörgensen (1911), girdle diameter $57\text{--}62\ \mu$; length left profile of hypotheca from base of horn to lower girdle list $36\text{--}38\ \mu$; length long apical horn $300\ \mu$ or more; length short apical horn $85\text{--}100\ \mu$.

The cell depicted by Cleve is a short-apical-horned posterior cell. Both monomorphic chains, with the long-apical-horned anterior cell similar to Cleve's iconotype (eg. Pavillard (1931) Pl. 3, Fig. 8), and dimorphic chains with the anterior cell belonging to *f. japonicum*, (eg. Karsten 1907), have been recorded. The long-apical-horned anterior cell of the chain figured by Jörgensen (1911, Fig. 151a), has a short left horn MBC radius coordinate, and differs from the anterior cell of a chain of *f. valdiviae* depicted by Karsten (1907, Pl. 48, Fig. 14b), only in the shorter MBC radius coordinate of the right horn.

Ceratium vultur f. japonicum (Schröder) Wood (1954): 305, Fig. 233c*, p.p. (anterior cell).

Sournia (1967): 481, Fig. 96.

C. japonicum Schröder (1906): 361, Fig. 33 a–c; Pavillard (1931): 93, Pl. 3, Fig. 9*, p.p. (anterior cell); Balech (1962): 182, Pl. 25, Fig. 393*, p.p. (anterior cell).

C. vultur var. *japonicum* (Schr.) Jörgensen (1911): 73, Pl. 8, Fig. 152a, b; Graham & Bronikowsky (1944): 41 Fig. 23E.

C. vultur: Dangeard (1927): 378, Fig. 42b*, p.p. (anterior cell); Böhm (1931b): 38, Fig. 35b*, p.p. (posterior cell); Peters (1932): 54, Pl. 1, Fig. 7b; Schiller (1937): 418, Fig. 459b (from Jörgensen (1911) Fig. 152).

C. robustum Ostenfeld & Schmidt (1901): 166, Fig. 17; Schröder (1906): 361, Fig. 31.

C. tripos robustum (O. & S.) Karsten (1907): 413, Pl. 48, Fig. 13a*, p.p. (anterior cell).

C. pavillardii: Wood (1954): 304, Fig. 232b.

Diagnosis: Differs from *f. vultur*, with which it is sometimes associated in chains as the anterior long-apical-horned cell, in that the recurved part of the antapical horns and the apical horn all lie parallel to one another, the left horn

*Chain depicted

degree coordinate with the 150 μ radius coordinate being $\leq 175^\circ$, (except in specimens with a very long left horn MBC radius coordinate, when it is less), and the left horn MRC is $\geq 45^\circ$; differs from *f. neglectum*, with which it has been recorded in a chain as the posterior cell and also *f. valdiviae* and *f. sumatranum* in that the left horn MBC radius coordinate is $>30 \mu$; differs further from *f. valdiviae* in that the left horn MRC is $>40^\circ$. (See Figs. 6N–R and 7D, E.)

Dimensions: In specimens examined: Girdle diameter 54–66 μ ; length hypotheca 30–39 μ ; length epitheca from centre of top girdle list to base of apical horn, 15–24 μ ; length long apical horn 480–570 μ . *From literature:* Girdle diameter 54 μ ; length hypotheca 38 μ ; length long apical horn 770 μ .

All chains incorporating *f. japonicum* depicted in the literature are dimorphic and two celled, with the posterior cell *f. vultur*, or the anterior cell *f. neglectum*. In NGY samples, only single, long-apical-horned cells were recorded.

Ceratum vultur f. neglectum (Karsten) Reinecke comb. nov.

C. tripos f. neglecta Karsten p.p. (1905): 146, Pl. 19, Fig. 12 non 12a.

C. vultur: Böhm (1931b): 38, Fig. 35b*, p.p. (anterior cell); Wood (1954): 304, Fig. 233a.

C. vultur var. japonicum: Graham & Bronikowsky (1944): 41, Fig. 23F.

Diagnosis: Differs from *f. japonicum* with which it has been recorded as the anterior long-apical-horned cell in a chain, in that the left horn MBC radius coordinate is $<30 \mu$; differs from *f. vultur* in that in the left horn the MBC radius coordinate is $<30 \mu$, the degree coordinate with the 150 μ radius coordinate is $>170^\circ$ and the recurved parts of the antapical horns lie roughly parallel to the apical horn; differs from *f. valdiviae* and *f. sumatranum* in that the left horn MRC occurs beyond the 45 μ radius coordinate. (See Fig. 6A, O.)

The single cells depicted in the literature have short apical horns. The specimen figured by Graham and Bronikowsky (l. c.) is unusual in that the angle made by a projection of the girdle and the hypothecal base is very large for the species, being 58° .

Ceratum vultur f. valdiviae Reinecke forma nova.

C. vultur: Okamura (1907): 129, Pl. 3, Figs. 1a*, 1c*.

C. vultur var. vultur: Graham & Bronikowsky (1944): 41, Fig. 23H.

C. tripos vultur: Karsten (1907): 414, Pl. 48, Figs. 14a*, b*.

C. sumatranum: Jørgensen p.p. (1911): 73, Pl. 8, Figs. 153, 154; Dangeard (1927):

*Chain depicted

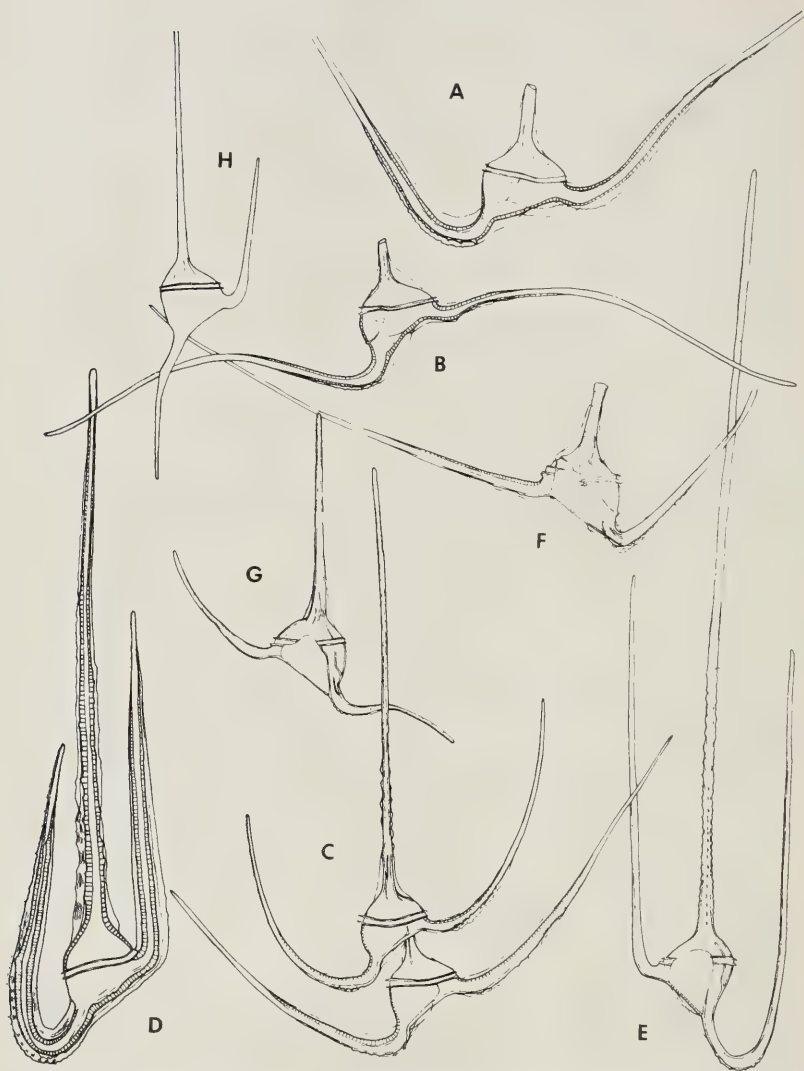


FIG. 7.

Specimens of Subsections *Robusta* and *Reflexa* from NGY Agulhas current samples: A—C *C. vultur* f. *valdiviae* Reinecke f. nov.; D and E *C. vultur* f. *japonicum* (Schröder) Wood; F *C. vultur* f. *sumatranum* (Karsten) Sournia; G *C. recurvum* (Jörgensen) Reinecke; H *C. reflexum* Cleve. Girdle diameters: A 63 μ , B 57 μ , C 54 μ , D 66 μ , E 54 μ , F 60 μ , G 57 μ , H 54 μ .

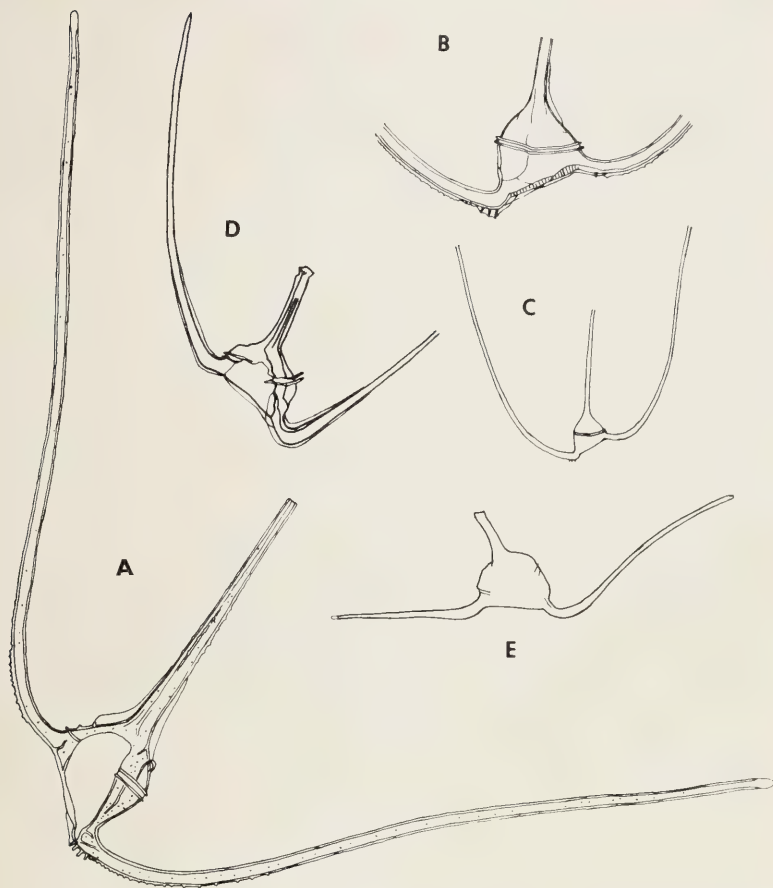


FIG. 8.

Specimens of *C. vultur* Cleve from NGY Agulhas current samples: A—D *C. vultur* f. *sumatranum* (Karsten) Sournia, B is an enlargement of the body and horn bases of C; E *C. vultur* f. *valdiviae* Reinecke f. nov. Girdle diameters: A 72 μ , B 66 μ , D 60 μ , E 54 μ .

378, Fig. 42c*; Böhm (1931b): 38, Fig. 35c*, Pl. 1; Balech (1962): 182, Pl. 25, Fig. 394*.

C. vultur var. *sumatranum*: Steemann Nielsen p.p. (1934): 27; Schiller (1937): 419, Fig. 460a, b (from Jörgensen (1911) Figs. 153, 154); Graham & Bronikowsky (1944): 41, Fig. 23D.

*Chain depicted

C. tripos neglectum Karsten p.p. (1905): 146, Pl. 19, Fig. 12a*, non Fig. 12.

Diagnosis: Differt a speciminibus multis *f. sumatrani* in eo quod °coordinatus cornus sinistri cum coordinato radii $30\ \mu < 100^\circ$ est; differt ab illis speciminibus *f. sumatrani* in quibus hic coordinatus $< 100^\circ$ est in eo quod °coordinatus cornus sinistri cum coordinato radii $90\ \mu < 145^\circ$ est, et coordinatus radii cornus dextri in loco flexi maximi retrorsum $> 22\ \mu$ est; differt a *f. vulture* in eo quod coordinatus radii cornus sinistri in loco flexi maximi retrorsum plerumque $< 30\ \mu$ est; specimina in quibus hic coordinatus $30\ \mu$ aequans a speciminibus rarissimis *f. vulturis* in quibus hic coordinatus $30\ \mu$ aequans differunt in eo quod °coordinatus cornus sinistri cum coordinatus radii $150\ \mu < 150^\circ$ est; differt a *f. neglecto* in eo quod in cornu sinistro, cursus mutationis maximi flexus per $15\ \mu$ intra coordinatum radii $45\ \mu$ accidit et °coordinatus cum coordinatus radii $150\ \mu < 170^\circ$ est; differt a *f. japonico* in eo quod cursus mutationis maximi flexum per $15\ \mu < 40^\circ$ est.

Diagnosis: Differs from most specimens of *f. sumatranum* in that the left horn degree coordinate with the $30\ \mu$ radius coordinate is $< 100^\circ$, and from those specimens of *f. sumatranum* in which this coordinate is $< 100^\circ$ in that the left horn degree coordinate with the $90\ \mu$ radius coordinate is $< 145^\circ$ and the right horn radius coordinate at the point of maximum backward curvature is $> 22\ \mu$; differs from *f. vultur* in that the left horn radius coordinate at the point of maximum backward curvature is generally $< 30\ \mu$, specimens in which this coordinate equals $30\ \mu$ differ from the occasional specimens of *f. vultur* in which this coordinate is $30\ \mu$ in that the left horn degree coordinate with the $150\ \mu$ radius coordinate is $< 150^\circ$; differs from *f. neglectum* in that in the left horn the maximum rate of change of direction of curvature over $15\ \mu$ occurs before the $45\ \mu$ radius coordinate and the degree coordinate with the $150\ \mu$ radius coordinate is $< 170^\circ$; differs from *f. japonicum* in that the left horn MRC is $< 40^\circ$. (See Figs. 5K, 6G, H, L, M, 7A–C and 8E.)

Dimensions: In specimens examined: Girdle diameter $54\text{--}63\ \mu$; length hypotheca $24\text{--}42\ \mu$; length epitheca $18\text{--}24\ \mu$; length long apical horn $348\ \mu$; length short apical horn $30\text{--}54\ \mu$. From literature: Jörgensen (1911), including *f. sumatranum*, diameter $64\text{--}71\ \mu$; length hypotheca $40\text{--}43\ \mu$; length apical horn $30\text{--}110\ \mu$, sometimes up to $400\ \mu$.

In chains with a long-apical-horned anterior cell, the antapical horns of the front cell are more forwardly directed than in the posterior cells. Recurvature of the distal parts of the antapical horns, usually only in the posterior cells, is quite common.

In NGY specimens, *f. valdiviae* was easily distinguished from *f. sumatranum*, but a survey of the literature indicates that the differences between the two are not sharp. Intermediates between *f. valdiviae* and *f. vultur* occur, but the former has never been recorded in chains with *f. japonicum*.

It is of interest to note that both *f. valdiviae* and *f. neglectum* were originally recorded by Karsten (1905) in only one and the same Atlantic sample.

Ceratium vultur f. sumatranum (Karsten) Sournia (1967) p.p.: 482.

C. tripos vultur var. sumatrana Karsten (1907): 413, 414, Pl. 48, Fig. 15a, b, Pl. 52, Fig. 14*.

C. vultur var. sumatranum (Karst.) Steemann Nielsen (1934) p.p.: 27, non Fig. 66; Schiller (1937) p.p.: 419, non Fig. 460; Wood (1954): 305, Fig. 233d; Ballantine (1961): 255, Fig. 55*.

C. sumatranum (Karst.) Jörgensen (1911) p.p.: 73, non Pl. 8, Figs. 153, 154; Nie (1936): 68, Figs. 31, 32*.

C. sumatranum f. angulatum Jörgensen (1911): 74, Pl. 8, Fig. 155.

C. vultur: Ostenfeld & Schmidt (1901): 167, Fig. 20*; Okamura (1907): 129, Pl. 3, Fig. 1b; Kofoed (1908) Fig. 9*; Kofoed (1909) Pl. 4, Fig. 7*; Klement (1964): 356, Pl. 2, Fig. 4*.

C. vultur var. reversum Graham & Bronikowsky (1944): 41, Fig. 23B.

C. vultur var. pavillardii: Graham & Bronikowsky (1944) p.p.: 41, Fig. 23C; non *C. pavillardii* Jörgensen.

Diagnosis: Generally differs from all other forms in that the left horn degree coordinate with the 30 μ radius coordinate is $\geq 100^\circ$, specimens of *f. sumatranum* in which this coordinate is $< 100^\circ$ differ from *f. valdiviae* in that the left horn degree coordinate with the 90 μ radius coordinate is $> 145^\circ$ and the right horn MBC radius coordinate is $< 22 \mu$; differs from *f. vultur* and *f. japonicum* in that the left horn MBC radius coordinate is $< 30 \mu$; differs from *f. neglectum* in that the left horn MRC occurs before the 45 μ radius coordinate. *F. sumatranum* is distinguished from *var. pavillardii* solely on grounds of distribution: the latter is confined to the Mediterranean, and is the only infraspecific taxon of *C. vultur* occurring there. (See Figs. 5C, D, F, G, J, L–N, 6F, 7F and 8A–D.)

Dimensions: *In specimens examined:* Girdle diameter 60–72 μ ; length hypotheca 27–42 μ ; length epitheca 15–36 μ ; length short apical horn 57–66 μ ; length long apical horn 210 μ . *From literature:* girdle diameter 43–71 μ ; length hypotheca 23–43 μ ; length short apical horn 34–110 μ ; length long apical horn up to 400 μ .

Karsten (1907: 413) referred to his new variety and the curvature of its antapical horns thus: “. . . hier finden sich ein Novum darin das es zu direkt Knickungen kommt, oder doch zu Krümmungen von so geringem Radius das der Eindruck von Knickungen hervorgerufen werden muss. Im Atlantischen Ocean scheinen die Formen zu fehlen . . .” It was Jörgensen (1911), who expanded the concept of “*C. sumatranum*” to include specimens of *f. valdiviae*.

*Chain depicted

Karsten himself (1907: 414), considered his "*C. tripos* var. *neglecta*" of 1905 to be characteristic of "*C. tripos* *vultur*".

F. sumatranum has been recorded singly and in complete monomorphic chains.

Ceratium vultur* var. *pavillardii (Jørgensen) Graham & Bronikowsky (1944) p.p.: 41, *non* Fig. 23C.

C. pavillardii Jørgensen (1911): 74, Pl. 9, Fig. 157a, b; (1920): 92, Fig. 83; Forti (1921): 70, Pl. 5, Fig. 56; Paulsen (1930): 90; Böhm (1931a): 364, Fig. 19; Rampi (1939): 307, Fig. 41; Halim (1960) Pl. 5, Fig. 8; *non* Dangeard (1927): 378 Fig. 42a (= *C. massiliense* (Gourret) Karst.); *nec* Wood (1954): 304, Fig. 232a, b (= *f. vultur*, *f. japonicum*).

C. vultur: Pavillard (1905): 54, Pl. 1, Fig. 2.

C. tripos var. *macroceras* *f. undulata* Schröder (1900): 16, Pl. 1, Fig. 17m*.

Diagnosis: Differs from *f. sumatranum* in that it occurs only in the Mediterranean, from which *f. sumatranum* is absent; differs from the other forms in that the left horn degree coordinate with the 30 μ radius coordinate is $> 100^\circ$.

Description: *Antapical horn curvature* similar to that in *f. sumatranum*: left horn degree coordinate with 30 μ radius coordinate $> 100^\circ$; left horn MBC radius coordinate $\leq 15 \mu$, this horn sometimes directed forwards from inception; MRC of right horn occurs between the 15 and 30 μ radius co-ordinates, rarely between the 30 and 45 μ , or between the 45 and 60 μ radius coordinates. **Thecal ornamentation:** thecal wall thin to thickened with longitudinal ridges; lists and spines absent, or listing varies from a small list in the angle between the base of the hypotheca and the left horn, to the occurrence of smooth- or slightly unevenly-margined lists along both sides of the proximal part of the apical horn, extending onto the epitheca; and along the base of the hypotheca, extending onto the proximal part of the left horn, and sometimes onto the base of the right horn, with a few spines supporting the left horn list in the region of recurvature; sometimes there is a list along the proximal part of the upper suture of the left horn. (See Fig. 5 A, B, E.)

Dimensions: *From the literature:* Jørgensen (1911), girdle diameter 74–85 μ ; length hypotheca 43–48 μ ; length apical horn 160–420 μ .

Distribution: This geographical variety is confined to the Mediterranean.

Jørgensen (1911) included his new species "*C. pavillardii*" in his Subsection *Vultur*, but omitted any comments on chain formation, merely giving the length of the apical horn as 160–420 μ . He noted that "*C. pavillardii*" could be confused with *C. vultur* and "*C. sumatranum*" from which it was distinguished by the very short, almost absent, basal part of the left horn. According to him,

"*C. pavillardii*" differed further from "*C. sumatranum*" in the longer more steeply sided epitheca, thecal ornamentation, and the less spreading horns. In 1920, Jörgensen observed that chains of "*C. pavillardii*" were relatively very frequent in his Mediterranean samples, and referred to Schröder's figure of a three-celled chain of "*C. tripos* var. *macroceras* f. *undulata*" from the Gulf of Naples. He also suggested that specimens from near Sicily listed as "*C. vultur*" by Cleve (1903), were in fact "*C. pavillardii*". Böhm (1931a) commented that chains were rarely found in the Adriatic, and recorded a greater percentage of short-apical-horned cells in winter.

Schröder's poor figure is the only published illustration of a chain of var. *pavillardii*. Here, the apical horns of the two posterior cells are about 0,25 the length of the apical horn of the anterior cell, as is typical of Subsection *Robusta*, but the ratio of the length of the apical horn to that of the body in the posterior cells is 1,5 and 1,9, which is higher than that recorded in other chains of this Subsection. This ratio is 1,4 in Böhm's figure of a short-apical-horned winter form.

The available evidence provides no sound justification for the separation of "*C. pavillardii* Jörg." as a distinct species from "var *sumatrana* Karsten". The fact that the former is the only morphological form of *C. vultur* recorded from the Mediterranean, where it appears to show relatively little variation, indicates that it should be treated as a geographic variety confined to this Sea, while specimens of *C. vultur* with the same abrupt recurvature of the left horn from other waters, are treated as belonging to f. *sumatranum*.

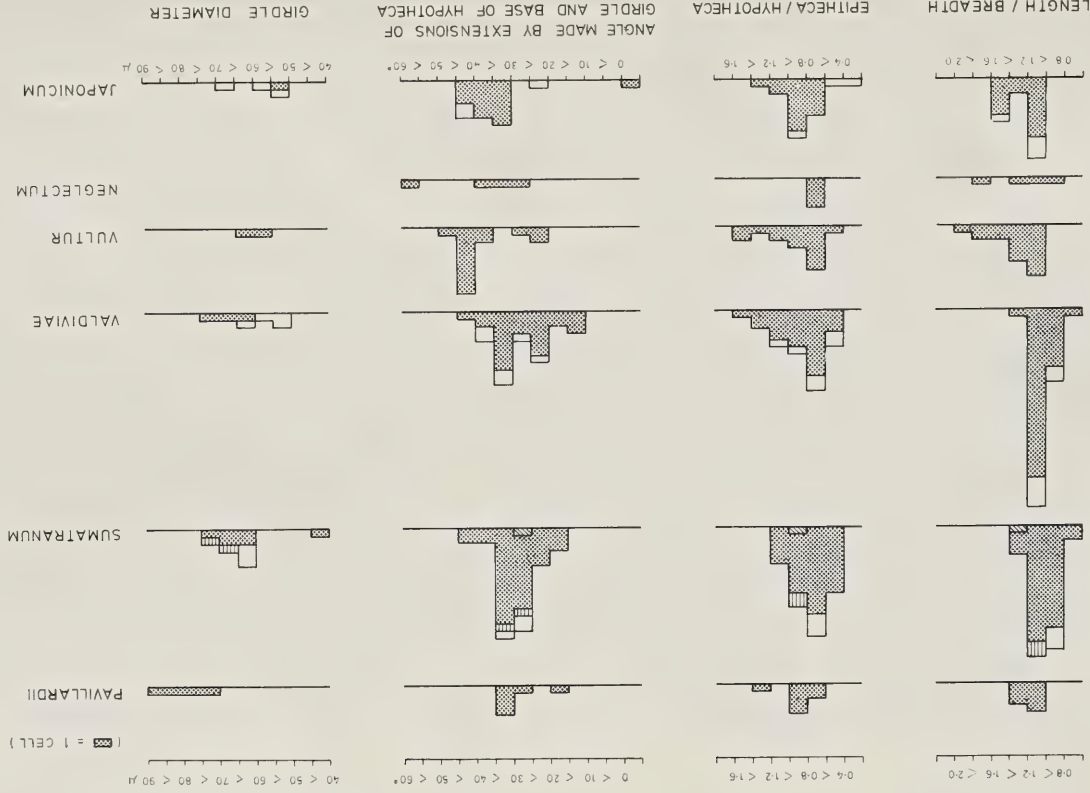
There are some minor differences between the latter and the Mediterranean var. *pavillardii*: prominent lists with markedly serrate or denticulate margins have not been depicted in figures of var. *pavillardii*, the ratio of the length of the epitheca to that of the hypotheca is more commonly 1,0 in var. *pavillardii* than in f. *sumatranum*, where it is mostly $< 0,8$, (see Fig. 9); the girdle diameter appears to be slightly larger in var. *pavillardii*, but the only measurements available are those of Jörgensen (1911).

Specimens referred to as "*C. pavillardii* Jörg." have been recorded outside the Mediterranean by Jörgensen (1911, 1920), from Atlantic, Indian and Pacific waters; by Steemann Nielsen (1939), in Indian and East Asian waters, with the same ecology and distribution as *C. vultur*; by Gaarder (1954), who noted chain formation, from the Atlantic, and by Graham and Bronikowsky (1944), who were the first to treat the taxon "*pavillardii*" as a variety of *C. vultur*. Sournia (1967) commented that this treatment was excessive. The only illustration of a specimen referred to by the epithet "*pavillardii*" from a locality outside the Mediterranean is that of Graham and Bronikowsky.

In the NGY samples, two specimens were found with long apical horns, which corresponded to Graham and Bronikowsky's figure, (see Fig. 8A-C).

Histograms showing variation in body shape in *C. vultur*: the dotted shading refers to specimens from the literature, the white to NGY specimens, the diagonal hatching to Graham & Bronikowsky's figure of "*C. vultur* var. *pavillardii*" (1944, fig. 23C, = *f. sumatranum*), and the vertical hatching to the NGY specimens of *f. sumatranum* which resemble it. (Dimensions of girdle diameter given in the literature by Jørgensen (1911), Nie (1936) and Klement (1964).)

Fig. 9.



All three differed from specimens of *var. pavillardii* depicted in the literature and other specimens of *f. sumatranum*, with regard to antapical horn curvature, only in the curvature of the right horn, where the MRC occurred between the 45 and 75 μ radius coordinate. In one NGY specimen, lists were absent from the antapical horns, but the proximal parts were denticulate along the lower sutures, with four of the denticles enlarged into spines in the region of recurvature of the left horn.

Ceratum recurvum (Jørgensen) Reinecke stat. nov.

C. sumatranum *var. recurvum* Jørgensen (1911): 74, Pl. 9, Fig. 156.

C. vultur *var. recurvum* (Jörg.) Graham & Bronikowsky (1944): 41, Fig. 23A.

C. vultur *var. sumatranum f. recurvum*: Schiller (1937): 419, Fig. 460c.

C. vultur f. recurvum: Sournia (1967): 483, Fig. 97.

C. vultur *var. sumatranum* "Endglied einer Kette" Steemann Nielsen (1934): 27, Fig. 66.

C. triplos buceros: Karsten (1907) p.p.: 409, Pl. 51, Fig. 8.

Diagnosis: Differs from the specimens of *C. vultur* with recurved antapical horns, in that a marked recurvature of the left antapical horn occurs in all cells, not just the posterior members of a chain; this recurvature occurs between the 45 and 75 μ radius coordinates, not beyond the 120 μ radius coordinate; the left horn is markedly angled at the point of recurvature, not gradually recurved, and does not extend beyond the 120 μ radius coordinate. Differs from *C. reflexum* in that the left horn degree coordinate at the point of recurvature exceeds 90°. (See Figs. 4, 6J, K and 7G.)

Description: *Antapical horn curvature:* The *left horn* degree coordinate with the 15 μ radius coordinate is generally 60–70°, (87° in the specimen figured by Graham and Bronikowsky l.c.); the MRC occurs between the 15 and 45 μ radius coordinates and is about 20°; the horn is recurved posteriorly between the 45 and 75 μ radius coordinates; at the point of recurvature the horn is "angled" and the thecal wall of the recurved part is thinner; the horn is short, not exceeding the 120 μ radius coordinates; the distal part may lie roughly parallel to the base of the hypotheca, or be directed posteriorly so that the horn tip is posterior to the point of inception of the horn. The *right horn* degree coordinate with the 15 μ radius coordinate is usually less than that of the left; the MRC occurs between the 15 and 30 μ radius coordinates and is less than that of the left horn; the distal part may be recurved, this recurvature being gradual or "angled"; when there is no recurvature, a slight kink may be present at about mid horn length, when the thecal wall suddenly becomes thinner; the right horn may extend to a longer radius coordinate than the left horn. Narrow *lists* with smooth or serrated margins may be present at the base of the apical horn, and a list may occur at the angle between the left side of the hypothecal

base and the base of the left horn; the proximal part of one or both antapical horns may be slightly spinose along the posterior edge. Two-celled chains have been recorded; the length of the apical horn of the posterior cell and of short-apical-horned single cells is about half that of the body; in long-apical-horned anterior and single cells, the length of the apical horn is 2.2–3.1 times that of the body; the length of the apical horn of the posterior cell of a chain is about 0.2 that of the anterior cell. The body is about as broad as long.

Dimensions: In two specimens examined: Girdle diameter 57 μ ; length hypotheca 36–39 μ ; length epitheca 18–24 μ ; length apical horn 162–172 μ . *From literature:* Jörgensen (l.c.), diameter 54 μ .

Distribution: Records scant, probably because it has been confused or included with *C. vultur*. It appears to be a very rare warm water species recorded from all oceans, but not found in the Mediterranean. Graham and Bronikowsky (l.c.) found it at only two stations in the Pacific, but common in the North Equatorial current of the Atlantic. (See Table 1.)

Steemann Nielsen (1934), who illustrated a posterior chain cell with a short apical horn, wrote: "Die »Varietät v. *recurvum*« Jörgensen« wurde öfters als Endglieder von Ketten, bei denen die ersten Glieder typische *sumatranum* warend gefunden. Solche »*recurvum*« -Zellen können nur als Degenerationerscheinungen aufgefasst werden." Schiller (l.c.) published three figures of what he called the anterior, hind and end chain members of *C. vultur* var. *sumatranum*. The first two are Jörgensen's figures of anterior and posterior cell members of what he called "*C. sumatranum*", the last is Steemann Nielsen's figure of *C. recurvum*. Later workers thus accepted Steemann Nielsen's conclusion. Graham and Bronikowsky, who considered *C. vultur* as consisting of various forms with numerous intergrades, published no convincing evidence of intergrades between "*C. vultur* var. *recurvum*" and other forms of *C. vultur* with recurved left antapical horns.

In the specimens and figures of *C. recurvum*, apart from that of Steemann Nielsen, which has truncated antapical horns, the tips of the antapicals are tapered and closed, and the left horn does not exceed the 120 μ radius co-ordinate, while in *C. vultur*, the tips of the antapicals are often truncate, and in all specimens examined, including those with truncate tips, the left horn exceeds the 150 μ radius coordinate.

Although the species has been illustrated but five times, and only two specimens were found in the present survey, all cells recorded show a uniformity of the diagnostic characters sufficient to justify the recognition of this taxon as a distinct species.

Steemann Nielsen appears to have confused *C. recurvum* with posterior chain members of *C. vultur* f. *valdiviae* with recurved antapical horns, such as illustrated by Okamura (1907, Pl. 3, Fig. 1a, see Fig. 6H).

Subsection **Reflexa** (Jørgensen) Reinecke stat. nov.

Section *Reflexa* Jørgensen (1911): 87.

Diagnosis: Distinguished by the curvature of the left antapical horn, which is abruptly recurved before the 90° coordinate so that it lies posteriorly directed and approximately in line with the apical horn.

Ceratium reflexum Cleve (1900): 15, Pl. 7, Figs. 8, 9.

Karsten (1907): 414, Pl. 48, Fig. 9; Jørgensen (1911): 87, Pl. 10, Fig. 184; Pavillard (1931): 94; Steemann Nielsen (1934): 25, Fig. 74; (1939): 15; Schiller (1937): 420, Fig. 461; Graham & Bronikowsky (1944): 45, Fig. 27H; Wood (1954): 305; (1963a): 40, Fig. 149a, b; Sournia (1967): 486, Fig. 99; *non* Silva (1955): 172, Pl. 9, Fig. 9 (= deformed specimen of an unidentifiable species belonging to Subsection *Macroceras*).

"*C. reflexum* Cleve forma" Schröder (1906): 366, Fig. 39.

C. vultur var. *productum* Wood (1963b): 16, Fig. 53.

Description: *Antapical horn curvature:* The left horn degree coordinate with the 15 μ radius coordinate is about 60°, the rate of change from the 15 to the 30 μ radius coordinate is <10°, and between the 30 and 45 μ radius coordinates, the horn begins a very gradual recurvature backwards, so that its distal part lies posteriorly directed almost in line with the apical horn; the proximal part of the horn is fairly broad, at the point of recurvature it may be slightly "angled", then it tapers to the tip. The right horn degree coordinate with the 15 μ radius coordinate generally exceeds that of the left horn; the degree coordinate with the 30 μ radius coordinate is > 90° and the MBC radius coordinate is short, being < 15 μ ; the distal part is generally not as slender as that of the left horn. The *apical horn* may be broad at its base or well delimited from the epitheca at inception. *Lists* with smooth to serrate margins may occur along the base of the hypotheca and the adjacent bases of the antapical horns, sometimes also along the base of the upper suture of the left horn, and along both sides of the base of the apical horn, which may instead be ornamented with spines. The *body* is as broad as long to about 1,3 times as long as broad. The ratio of apical horn: body length varies from 1,8—3,0. (See Figs. 6S and 7H.)

Apart from specimens with truncate antapical horns depicted by Steemann Nielsen (1934) and Wood (1963a), the antapical horns of all specimens illustrated in the literature and the single specimen found in the present survey, end in a tapered tip, and do not exceed the length of the apical horn, being about greater than or equal to half its length. There is no record of the occurrence of chains in this species.

Dimensions: In single specimen examined: Girdle diameter 54 μ ; length body 63 μ ; length hypotheca 42 μ ; length epitheca 15 μ ; length apical horn 192 μ .

From literature: Jörgensen (l.c.), girdle diameter 55–58 μ ; length hypotheca 37–43 μ ; length of apical horn 170–220 μ .

Distribution: A very rare warm water species, recorded from all the oceans, but not the Mediterranean. Graham and Bronikowsky (l.c.) classify it as "intolerant, tropical . . . probably a shade species". (See Table 1.)

Jörgensen considered that there was a distinct relationship between *C. reflexum* and what he called *C. sumatranum* var. *recurvum*. There is some similarity in the relative shortness of the antapical horns, the recurvature of the left horn, and, in the NGY specimens, the left profile of the hypotheca. Although the curvature of the left horn in a specimen depicted by Cleve (l.c. Fig. 8), is such that it forms an oblique angle, rather than a straight line, with the apical horn, no true intermediates between the two have yet been recorded.

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	Radius coordinates in radius units					30	35	40	45	50	Int.	X	Int.	X	X	Int.	X	X ²	X ³	Int.	X	X ²	X ³	X ⁴	
	5	10	15	20	25																				
Degree Coordinates	MASSILIENSE																								
	97	102	109	116	124	133	140.5	146.7	151	155	89.55	1.38	86.62	1.67	-0.01	93.91	0.38	0.05	-0.0007						
	90	100	108	115.5	123	130	136.3	141	144.7	148.7	87.87	1.30	79.97	2.09	-0.01	80.70	1.96	-0.01	-0.0001						
	80	94	102.5	112	120.5	129.5	137	143	147	151	78.43	1.57	68.06	2.61	-0.02	69.07	2.43	-0.01	-0.0001						
	77	84	92	102	112	121	129	134.5	139	142	145	79.60	1.46	65.39	2.88	-0.03									
	77	87	96	106	116	124	130.5	135	139	143	71.23	1.52	63.15	2.32	-0.01	70.65	1.00	0.04	-0.0007						
	77	84	96	107	117	124	130	136	140.3	144.2	73.05	1.55	62.12	2.64	-0.02	66.43	2.05	0.00	-0.0003						
	70	78	103	116	126	133	139	143	147	150	76.53	1.65	57.62	3.55	-0.03	55.50	3.92	-0.05	0.0002						
	70	79	88	100	114	125	135	143	150	155	60.73	2.01	53.82	2.70	-0.01	63.37	1.00	0.06	-0.0009						
	58	65	89	114	131	141	147	151.5	155.5	159	55.63	2.38	24.92	5.45	-0.06	30.85	4.40	-0.01	-0.0006	63.40	-3.90	0.60	-0.0171	0.0002	
	78.1	87.5	99.2	111	121.6	130.4	137.3	142.6	146.8	150	74.88	1.66	61.81	2.96	-0.02	65.93	2.23	0.01	-0.0004						
	TRICHO CEROS Diam. less than or equal to 42μ																								
	70	76	82	89	95	103	114	125	136	144	57.13	1.69	65.68	0.84	0.02	68.07	0.41	0.03	-0.0002	56.79	3.31	-0.18	0.0056	-0.0001	
	66	72	74	77	81	84	86.5	89	94	101	63.17	0.70	64.92	0.53	0.00	60.22	1.36	-0.03	0.0004						
	65	74	77.5	81	84	87	90	94.5	99	109	63.23	0.83	64.98	0.66	0.00	55.18	2.40	-0.07	0.0009						
	61	69	75	80	84	87	93	99	106	117	56.27	1.12	59.68	0.78	0.01	50.43	2.42	-0.06	0.0009						
	50	60	65	69	73	77	83	91	99	111	44.53	1.21	50.53	0.61	0.01	40.13	2.46	-0.07	0.0010						
	62	69.5	73.3	78.5	83.3	89.9	98.8	108.1	117.8	128.3	51.68	1.43	60.85	0.51	0.02	57.86	1.04	-0.01	0.0003						
	TRICHO CEROS Diam. greater than or equal to 45μ																								
	78	80	84	88	92	99	107	119	129	135.5	64.50	1.33	76.75	0.11	0.02	79.57	-0.39	0.04	-0.0003						
	78	78	82	87	93	100	109	123	137	145	60.07	1.57	76.98	-0.12	0.03	80.54	-0.75	0.06	-0.0003						
	77	80	83	87	92	98	105	117	132	142	61.80	1.44	79.13	-0.29	0.03	75.40	0.37	0.00	0.0003						
	74	76	79	85	91	98	111	133	143	147	54.63	1.79	72.55	-0.00	0.03	84.33	-2.09	0.12	-0.0011	62.22	3.60	-0.29	0.0101	-0.0001	
	71	76	81	85	92	101	112	128	141	147	54.45	1.78	68.81	0.35	0.03	74.01	-0.57	0.07	-0.0005	57.03	3.81	-0.29	0.0083	-0.0001	
	73.9	76.9	80.7	86.2	92.7	100.7	112	125	138.7	147.1	56.78	1.70	72.09	0.16	0.03	76.04	-0.54	0.06	-0.0004	66.74	1.85	-0.12	0.0044	-0.0000	
MACRO CEROS From Norway																									
50	54	67	80	103	121	135	146	153	159	31.73	2.73	24.57	3.44	-0.01	49.47	-0.97	0.18	-0.0023							
44	48	54	63	75	89	107	120	130	138	23.50	2.30	32.75	1.38	0.02	49.78	-1.64	0.15	-0.0016							
40	48	59	77	95	115	129	139	148	155.3	23.41	2.81	15.60	3.58	-0.01	36.02	-0.04	0.14	-0.0019							
40.2	46.1	56.9	72.5	97.9	120	132.4	145.6	152.7	156.6	20.77	2.96	11.55	3.88	-0.02	42.00	-1.52	0.21	-0.0028							
MACRO CEROS NGY Specimens																									
39	50	62	80	113	121.3	127	133	137	141	42.55	2.26	10.20	5.49	-0.06	2.91	6.79	-0.11	0.0007	21.95	1.93	0.24	0.0090	0.0001		
35	43	60	83	95	104	110	115	121	126	31.37	2.11	10.24	4.22	-0.04	12.52	3.82	-0.02	-0.0002	36.99	-2.42	0.44	-0.0127	0.0001		
35	42	60	77	88	96	101	105.7	109.3	112.3	33.45	1.79	12.68	3.87	-0.04	14.93	3.47	0.02	-0.0002	32.70	-1.05	0.31	-0.0092	0.0008		
33	42	60	75	85	92	97	100.7	104	106.3	33.83	1.66	12.42	4.80	-0.04	12.08	3.86	-0.04	0.0000	25.45	0.45	0.21	-0.0068	0.0001		
36.8	49.2	72.8	89.6	100.4	109.1	115.7	121.7	126.1	127.5	38.72	2.04	12.74	4.64	-0.05	10.95	4.96	-0.06	0.0002							
DEFLEXUM																									
60	62	72	95	128	145	155	162	167	171	42.33	2.89	23.00	4.82	-0.04	56.71	-1.16	0.22	-0.0031	97.35	-11.54	0.98	-0.0239	0.0002		
55	62	75	125	153	163	170.3	175	179.3	182.5	46.89	3.17	5.70	7.29	-0.07	27.66	3.39	0.09	-0.0020	93.01	-13.32	1.32	-0.0355	0.0003		
55	65	82	104	124	137	144.7	151	155.5	159.5	49.30	2.50	24.71	4.95	-0.04	36.55	2.85	0.05	-0.0011	61.36	-3.50	0.51	-0.0138	0.0001		
54	63	78	103	129	145	155	161	166.5	170.7	43.79	2.86	18.64	5.38	-0.05	39.59	1.66	0.12	-0.0020	71.77	-6.55	0.72	-0.0184	0.0001		
40	42	51	78	126	144	160	166	169	172.9	18.93	3.43	-7.82	6.10	-0.05	38.38	-2.09	0.31	-0.0043	95.91	-16.78	1.38	-0.0337	0.0001		
52.5	59.3	73.7	106	137.1	151.3	160.1	165.7	169.7	172.9	41.76	3.02	10.00	6.20	-0.06	35.98	1.59	0.14	-0.0024	83.23	-10.48	1.02	-0.0265	0.0002		
C. VULTUR F. SUMATRANUM																									
77	104	115	122	127	132	135	139	143	147	88.53	1.29	69.95	3.15	-0.03	51.76	6.38	-0.17	0.0017	37.39	10.09	-0.44	0.0091	-0.0001		
90	105	115	122	129	134	138	142	146.5	150	93.20	1.23	81.03	2.45	-0.02	73.73	3.75	-0.08	0.0007							

POLAR COORDINATES

RESULTANT POLYNOMIAL REGRESSIONS

APPENDIX TABLE 1. Showing polar coordinates and the resultant intercepts and regression coefficients calculated using a Polynomial Regression program for the portion of the left antapical horn between radius coordinates of 15μ and 150μ, in a selection of specimens of Section *Macroceras*. All specimens are from the line of NGY stations off Port Elizabeth, with the exception of some from Norwegian waters. Apart from *C. vultur f. sumatranum*, the specimens are grouped in taxa of unspecified rank, approximating those previously described in the literature. (1 radius unit equals approximately 3μ; Int. = intercept; underlined figures represent the mean degree coordinates calculated for each radius coordinate for all specimens examined, and the resultant polynomial regressions.)

APPENDIX TABLE 2. SHOWING VARIATION IN POLAR COORDINATES IN SPECIMENS OF *CERATIUM VULTUR* SELECTED FROM THE LITERATURE

TAXON	MAX. RATE OF CHANGE OVER 5 R.U. AFTER INITIAL CHANGE FROM 0-5 R.U.				° COORDS AT POINT OF MAXIMUM BACKWARD CURVATURE				LEFT HORN ° COORDS				LITERATURE REFS.	
	Position along horn		Rate in °		Degree		Radius		coords		at			
	L. Horn	R. Horn	L. Horn	R. Horn	L. Horn	R. Horn	L. Horn	R. Horn	L. Horn	R. Horn	10 R.U.	30 R.U.		50 R.U.
F. VULTUR	15-20	10-15	28	15.5	50	70	57.5	77	7.5	12.5	53	126	146	Cl. (1900) Pl. 7, fig. 4
{ F. VULTUR F. VULTUR { F. VULTUR	30-35	10-15	12.5	12	77	57	80	67.5	10.7	13.0	78	113	153	Pa. (1931) Pl. 3, fig. 8
	15-20	—	17	—	63	—	72.5	—	—	10.0	72.5	127	154	
	25-30	5-10	13	20	67	67	54	70	5.5	21.0	40	75	105	
{ F. JAPONICUM { F. VULTUR { F. VULTUR	20-25	5-10	78	26	43	80	53	75	4.0	19.5	43	155	181	K. (1907) Pl. 48, fig. 13a
	15-20	5-10	30	22.5	65	80	71	75	4.0	11.5	68	147	169	
	5-10	5-10	21	24	57	45	63	55	7.5	6.5	78	133	165	J. (1911) Pl. 8, fig. 151a
F. JAPONICUM	15-20	5-10	19.5	10.5	57	77	72	78	6.5	11.5	68	127	156	
F. JAPONICUM	30-35	5-10	63	23	54	80	61	75	4.0	23.0	55	77	175	Schr. (1906) Fig. 33c
F. JAPONICUM	25-30	15-20	48	17	23	50	40	62	11.0	24.7	25	86	153	Schr. (1906) Fig. 31
F. JAPONICUM	15-20	5-10	72	30	50	45	58	55	7.5	14.5	52.5	164	185	O. & S. (1901) Fig. 17
F. JAPONICUM	20-25	5-10	45	13	60	86	68	83	3.8	13.5	65	155	184	G. & B. (1944) Fig. 23E
{ F. NEGLECTUM { F. JAPONICUM	20-30	5-10	18	14	77	65	80	76	9.0	6.5	87	151	183	Bö. (1931b) Fig. 35b
	20-25	5-10	48	16	57	67	68	70	7.0	11.5	67	167	194	
F. NEGLECTUM	25-30	5-10	23	11	65	77	70	78	5.5	8.5	75	146	182	K. (1905) Pl. 19, fig. 12
F. NEGLECTUM	25-30	10-15	22	17.5	85	47	88	55	10.0	7.0	88	135	175	G. & B. (1944) Fig. 23F
{ F. VALDIVIAE F. VALDIVIAE { F. VALDIVIAE	5-15	10-25	10	4	65	67	75	77	18.0	10.0	75	112	137	K. (1905) Pl. 19, fig. 12a
	10-15	10-20	15	2	56	71	73	73	26.0	8.5	75	113	122	
	5-10	10-20	14.5	2	58	77	72.5	83	28.0	10.0	72.5	111	132	
F. VALDIVIAE	5-10	10-15	20	10	65	60	73	68	11.3	7.0	85	133	151	K. (1907) Pl. 48, fig. 14a
{ F. VALDIVIAE { F. VALDIVIAE	10-15	5-10	16.5	10	60	60	67.5	72	11.5	10.0	67.5	122	142	
F. VALDIVIAE	10-15	10-20	18	10	75	43	77	60	17.0	7.8	84	137	162	K. (1907) Pl. 48, fig. 14b
{ F. VALDIVIAE { F. VALDIVIAE	10-15	5-10	15	9	55	73	65	75	8.0	9.5	68	113	128	
F. VALDIVIAE	5-10	10-15	26	9	50	80	60	84	9.0	6.5	76	127	151	Ok. (1907) Pl. 3, fig. 1a
F. VALDIVIAE	5-10	5-10	14.5	11	68	67	70	75	8.0	6.5	82.5	122	138	
F. VALDIVIAE	10-15	5-10	24.5	17	68	60	72	65	7.5	6.0	88	135	141	
{ F. VALDIVIAE { F. VALDIVIAE	5-10	5-10	29.5	12	58	58	63	67	8.5	6.0	87.5	128	136	
F. VALDIVIAE	5-10	10-15	24	12	70	50	73	64	12.0	5.7	94	143	170	J. (1911) Pl. 8, fig. 153
F. VALDIVIAE	10-15	10-15	17.5	6	75	75	77	80	12.0	7.0	87.5	141	160	G. & B. (1944) Fig. 23H
F. VALDIVIAE	10-15	5-15	20	5.5	53	57	63	72.5	20.0	7.5	72	125	44	G. & B. (1944) Fig. 23D

APPENDIX TABLE 2. SHOWING VARIATION IN POLAR COORDINATES IN SPECIMENS OF *CERATIUM VULTUR* SELECTED FROM THE LITERATURE (continued)

TAXON	MAX. RATE OF CHANGE OVER 5 R.U. AFTER INITIAL CHANGE FROM 0-5 R.U.				° COORDS AT 5 R.U.		POINT OF MAXIMUM BACKWARD CURVATURE			LEFT HORN ° COORDS						LITERATURE REFS.
	Position along horn		Rate in °				Degree	coords	Radius	coords	at	at	at			
	L. Horn	R. Horn	L. Horn	R. Horn	L. Horn	R. Horn	L. Horn	R. Horn	R. Horn	L. Horn	10 R.U.	30 R.U.	50 R.U.			
F. SUMATRANUM	10-15	5-10	25	15	78	75	78	76	5,5	5,0	95	155	170	G. & B. (1944) Fig. 23B		
{ F. SUMATRANUM	5-10	5-10	21,5	21	75	59	75	63	5,5	5,0	96,5	149	—	Ko. (1908) Fig. 9		
F. SUMATRANUM	5-10	5-10	29	18	43	74	52	74	5,0	7,3	72	143	—			
{ F. SUMATRANUM	10-15	5-10	46	32	58	50	67	55	5,5	8,0	86	163	*174	K1. (1964) Pl. 2, fig. 5		
F. SUMATRANUM	10-15	5-10	35,5	22	70	60	68	65	6,5	4,8	102	166	174			
F. SUMATRANUM	5-10	5-10	35	25,5	70	63,5	68	58	4,7	4,5	105	162	168			
{ F. SUMATRANUM	5-15	5-10	35	10	50	70	60	72	6,5	8,5	85	141	*149	O. & S. (1901) Fig. 20		
F. SUMATRANUM	5-10	5-10	35	13	77	67	78	73	7,5	5,5	112	150	159			
{ F. SUMATRANUM	5-10	5-10	28	10	90	75	73	77	6,0	3,0	118	169	189	Ko. (1909) Pl. 4, fig. 7		
F. SUMATRANUM	10-15	5-10	21	14,5	95	78	85	75	4,0	3,5	113	163	180			
F. SUMATRANUM	5-10	5-10	27,5	15	85	80	80	78	4,7	3,5	112,5	158	174			
F. SUMATRANUM	10-15	5-10	29,5	10	92,5	87	70	85	4,5	2,0	102,5	161	175			
F. SUMATRANUM	10-15	5-10	28	16	75	78	75	75	4,5	5,0	96	153	167			
F. SUMATRANUM	5-10	5-10	30	12,5	90	80	80	74	7,0	2,5	120	165	177			
F. SUMATRANUM	5-10	5-10	28	13	70	85	75	82	4,0	6,0	98	154	167			
F. SUMATRANUM	10-15	5-10	26	18	70	70	73	65	4,5	5,5	94	155	169			
F. SUMATRANUM	5-10	5-10	36	8	93	105	87	90	0,0	4,5	129	166	176			
F. SUMATRANUM	5-10	5-15	24	7	83	88	85	86	4,5	5,5	107	159	171			
F. SUMATRANUM	10-15	5-10	45	14	55	75	64	75	5,0	8,5	75	157	170			
F. SUMATRANUM	5-10	5-10	28	15,5	85	72	83	72	5,0	4,5	113	159	170			
F. SUMATRANUM	5-10	5-10	35	16	55	60	62	66	7,0	6,0	90	155	170			
{ F. SUMATRANUM	5-10	5-10	35	15	70	58	70	68	8,0	5,0	105	145	155	K. (1907) Pl. 51, fig. 14		
F. SUMATRANUM	5-10	5-10	35	10,5	65	67	67,5	72	7,5	5,5	100	145	156			
{ F. SUMATRANUM	—	—	—	—	—	—	—	—	—	—	—	—	—	Nie (1936) Fig. 32		
F. SUMATRANUM	10-15	5-10	32	25	75	45	75	57	7,5	4,5	105	165	173			
F. SUMATRANUM	10-15	5-10	21	20	87	58	80	65	6,5	3,5	107	158	170			
F. SUMATRANUM	5-10	5-10	49,5	16	73	58	70	68	8,5	4,5	122,5	155	—	J. (1911) Pl. 8, fig. 155		
F. SUMATRANUM	5-10	15-25	22,5	6	95	77	75	80	13,0	4,0	117,5	144	155	G. & B. (1944) Fig. 23C		
V. PAVILLARDII	5-10	5-20	37,5	8	85	77	63	80	7,0	3,5	122,5	156	168	J. (1911) Pl. 9, fig. 157a		
V. PAVILLARDII	5-10	5-10	33	14	85	93	80	80	2,0	3,5	118	149	158	Pa. (1905) Pl. 1, fig. 2		
V. PAVILLARDII	5-10	5-10	20	5	105	90	90	85	3,5	0,0	125	154	—	Bö. (1931a) Fig. 19		
V. PAVILLARDII	5-10	10-15	42	12	73	55	73	67	11,5	5,0	115	162	177	Ra. (1939) Fig. 41		

The figures were photographed and printed at approximately the same scale as the camera lucida drawings of the NGY specimens. These measurements are subject to some error. (R.U. = radius unit, one radius unit is approximately equal to 3 μ ; brackets indicate individuals of a chain; * indicates value estimated. Radius coordinates given in R.U.)

APPENDIX TABLE 3. SHOWING THE RELEVANT POLAR COORDINATES USED TO CLASSIFY SPECIMENS OF *CERATIUM VULTUR* FOUND IN AGULHAS CURRENT NGY SAMPLES, WITH A KEY TO THE TAXA FOUND

MAX. RATE OF CHANGE OVER 5 R.U. AFTER INITIAL CHANGE FROM 0-5 R.U.	° COORDS AT 5 R.U.	POINT OF MAXIMUM BACKWARD CURVATURE	LEFT HORN° COORDS
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<i>Position</i>	<i>Rate in °</i>	<i>Degree coords</i>	<i>Radius coords</i>
L. Horn	R. Horn	L. Horn	R. Horn
along horn			
10 R.U.	30 R.U.	10 R.U.	30 R.U.
		at	at

[illegible]

(** indicates right horn directed laterally or approximately parallel to base of hypotheca after inception; * indicates right horn recovered posteriorly after inception; brackets indicate chain of two cells.)

KEYS TO SPECIMENS FOUND:

- (1) Left horn degree coordinate with 10 R.U., less than 100°;
S 10° Spectra degrees north
- (2) Left horn degree coordinate with 10 R.U., greater than 100°
S 10° Spectra degrees north
- F. SUMATRANUM
- F. VALDIVIAE